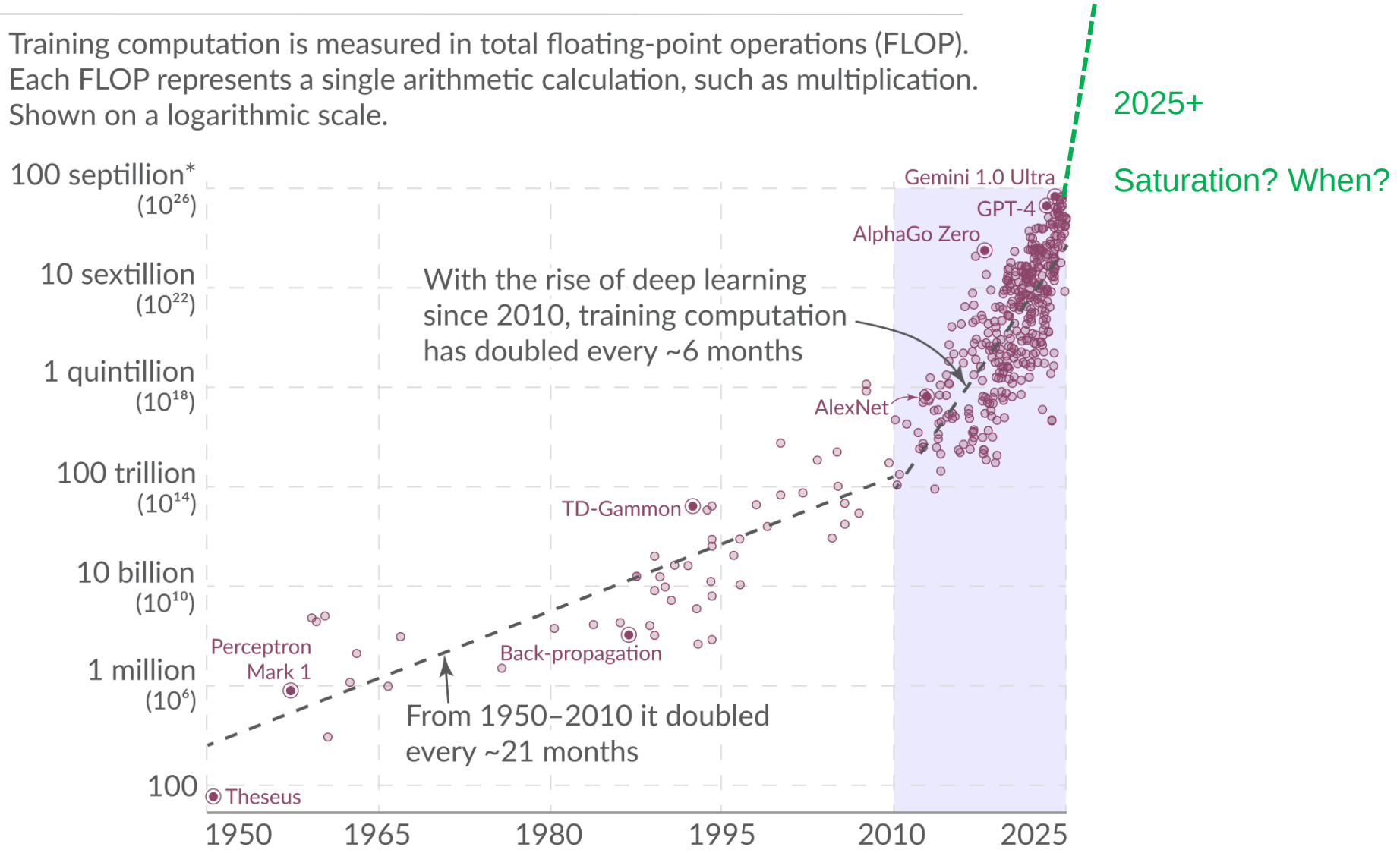
AI in Mobility

Daniel Watzenig
May 27, 2025

- AI breakthroughs
- AI applications
- AI examples
- Takeaways

The rise of AI

The computation used to train notable AI systems has doubled **every appr. 6 months since 2010!**



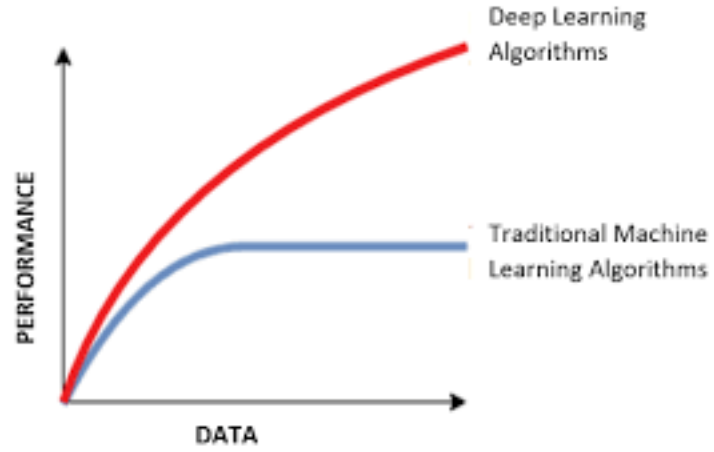
Epoch, 2024

AI: 1950+

Neural networks (NN)
Knowledge engineering
Expert systems

Machine learning (ML)
Statistical learning
Supervised learning
Cognitive systems
Intelligent systems

AI beyond “narrow”
Reinforcement learning
Unsupervised learning
Deep learning (DL), SNN
GenAI, AgenticAI, PINNs



1950	2012	2013	2016	2022	2023	2024	2025+
“Turing Test” by Alan Turing	“Big Bang” DL Turning point	CUDA/GPU (Nvidia)	DGX-1	ChatGPT	Rise of GenAI	AgenticAI	Common-Sense Safe & secure AI Multi-purpose Automation Strong AI

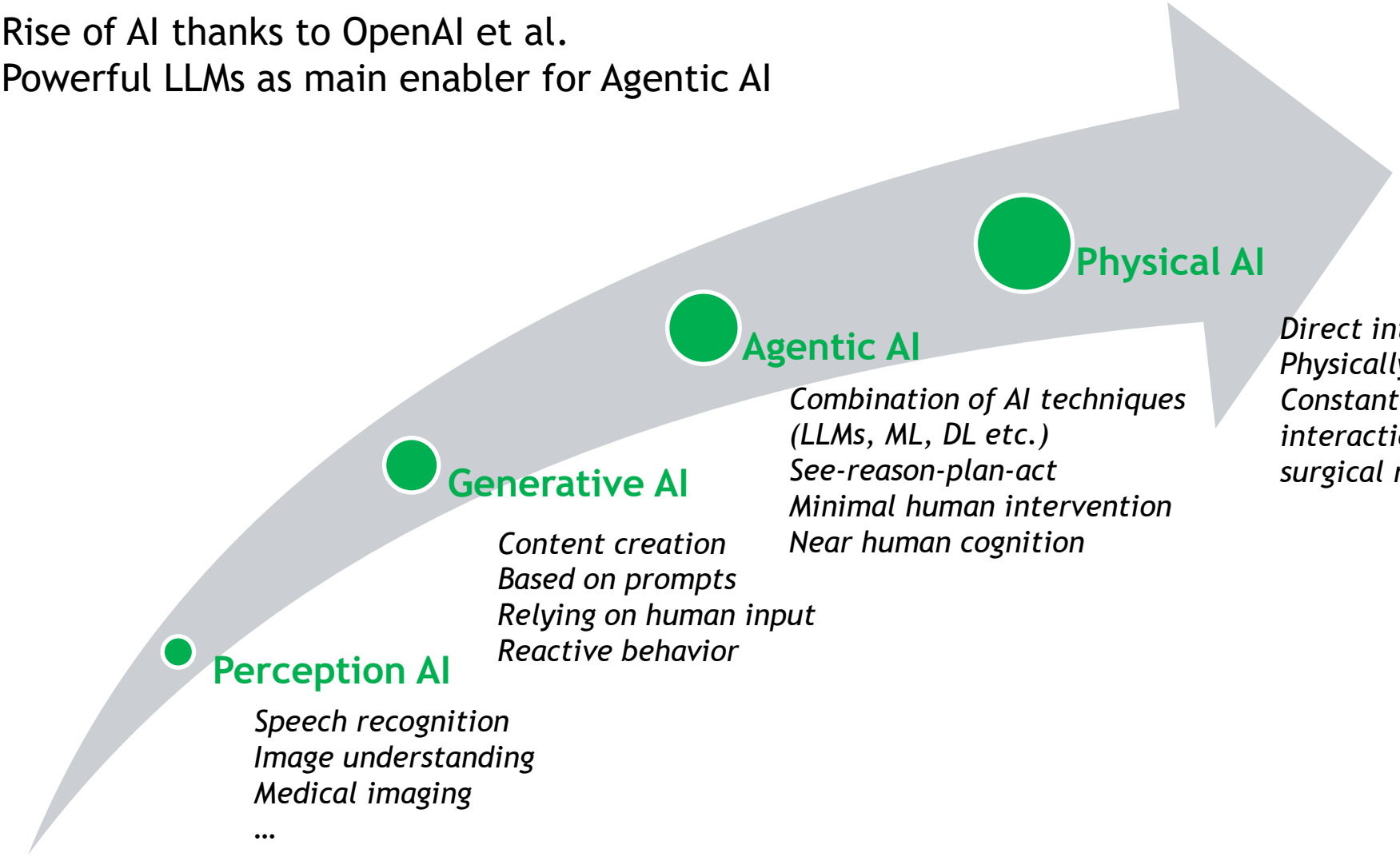
AlexNet (Krizhevsky) a DL model wins the ImageNet Large Scale Visual Recognition Challenge (50% less errors), use of GPU chips

- IBM Watson, Jeopardy (2011)
- Google DeepMind Alpha Go (2015)
- DeepMind AlphaFold2, protein-folding problem (2020)
- Sora, text-2-video model for generating videos (2024)

virtual vehicle

Perception AI | Gen AI | Agentic AI | Physical AI

- Rise of AI thanks to OpenAI et al.
- Powerful LLMs as main enabler for Agentic AI



[based on: J. Huang, Nvidia, CES Keynote, Las Vegas, NV, 01/2025]

Opportunities for innovations in mobility and transport

Key examples with significant impact

- Driver assistance and self-driving cars
- Personalized driving experience
- Automation of processes relying on large data volume
- Proactive decision making and support of decision making
- Manufacturing (Supply chain optimization, cobots, digital twins, computer vision)
- Predictive maintenance and predictive analytics
- Company
  - Upskilling
  - IT performance optimization
  - AI-driven business reinvention (process & product & portfolio)

→ **Product, process, production, operation**

AI in automotive SW development

D. Watzenig

AI in automotive SW development

Some statements by relevant automotive stakeholders

- *“At Toyota, we create very detailed specification and requirements documents for everything we do at the beginning of a project. It would be great if we could feed those documents into a large language model (LLM) and have it automatically generated into a robust testing suite.”*

  Dave Tsai | Vice President of Engineering, Toyota Connected

- *“The quantity of testing that must be done drives a need for automatic failure discovery of current models”*

  Nvidia Automotive Software Team

Five software development challenges in automotive and how AI is addressing them, commissioned by Aurora Labs (Sam Abuelsamid), 2024.

AI in automotive SW development

Some statements by relevant automotive stakeholders

- *"Generative AI and large language models (LLM) can be used to generate architecture and design patterns that are optimized for the automotive industry and can be relied on from a safety point of view"*
  Oren Sokoler | CTO, Aurora Labs

- *"We generate tremendous amounts of data in the course of testing as well as running in production. The resources needed to manually filter through that and find the data that can help us debug and improve a product are enormous. A tool that can parse that data and isolate the useful data would speed up development and reduce cost."*
  Lisa Perez Savage | Safety Technical Lead, Aptiv

Five software development challenges in automotive and how AI is addressing them, commissioned by Aurora Labs (Sam Abuelsamid), 2024.

Where might AI create impact in SW development?

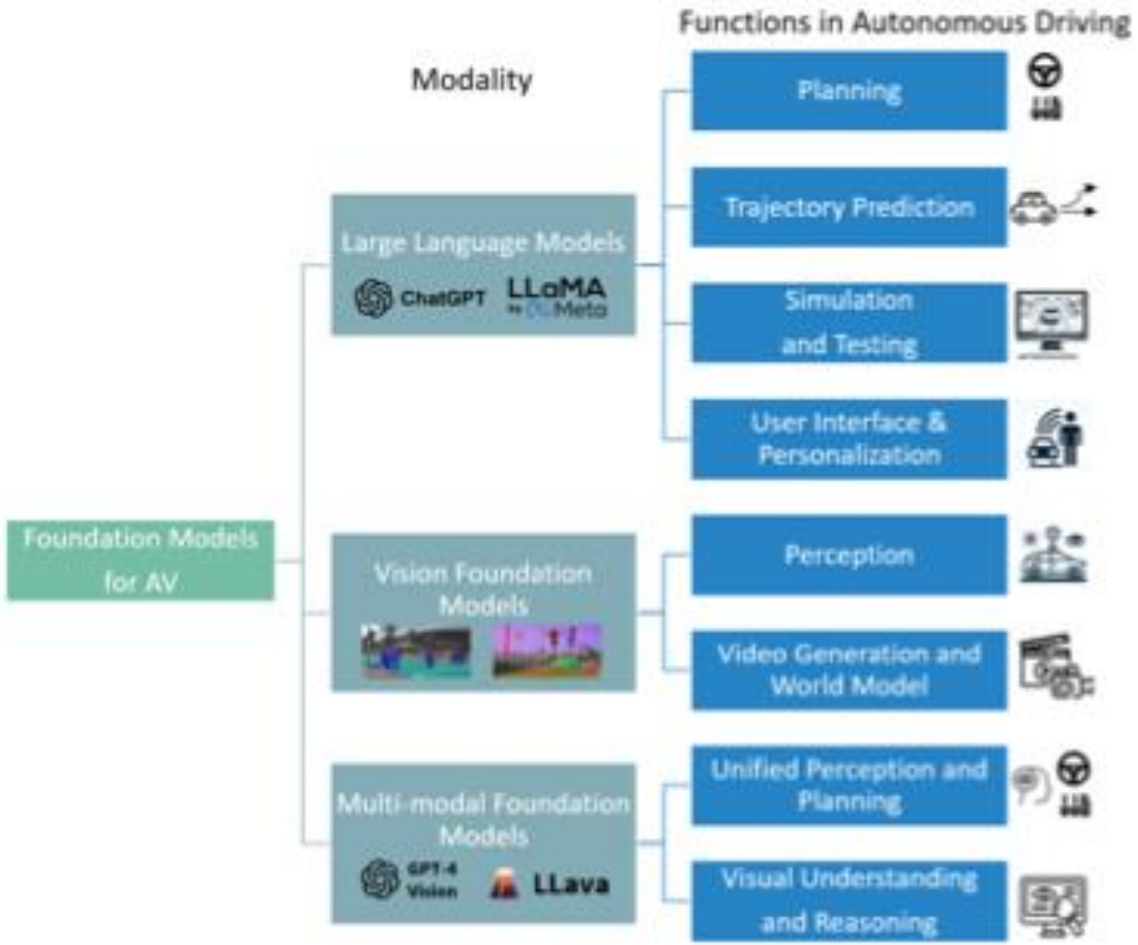
Key examples with significant impact

- Analyzing vast amounts of data
- Simulating scenarios
- Identifying bugs and errors
- Automate code generation
- Optimize workflows
- Perform code reviews
- Enhance/improve of code quality (reduction in dev time)
- More efficient software development cycles
- Auto-completion plugins can significantly speed up the coding process
- Convert high-level specifications into code, reducing potential errors

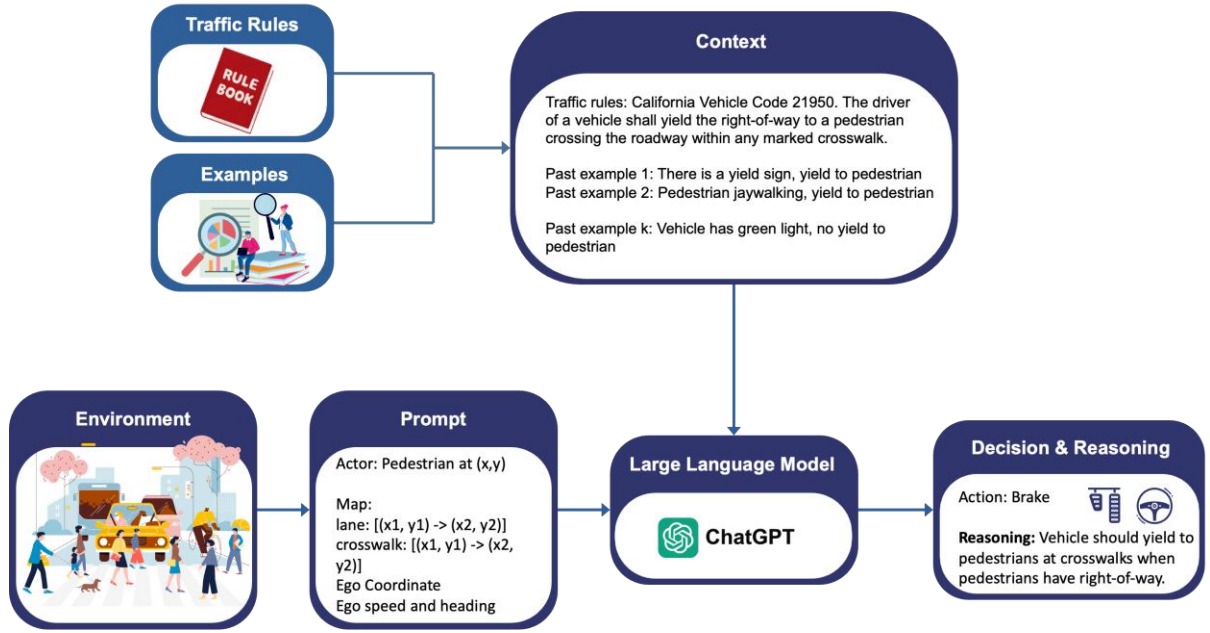
…

AI in mobility – examples

Foundation models (FM) in autonomous driving



FMs in autonomous driving

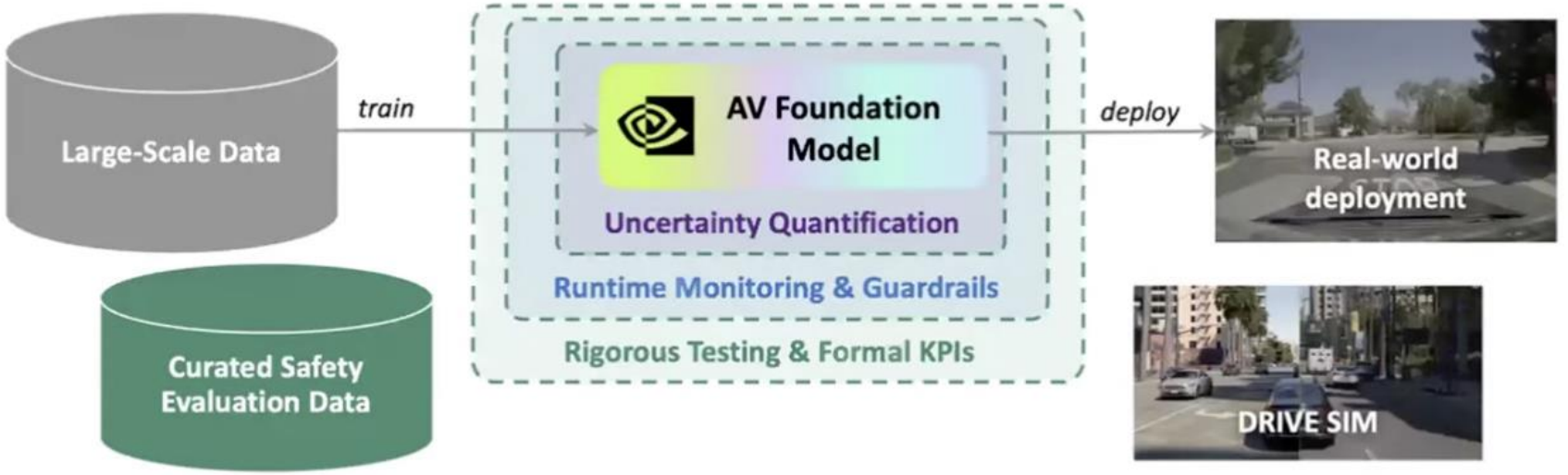


Common pattern of LLM pipelines for autonomous driving: integration of textual environment descriptions and LLM reasoning (Source: Virtual Vehicle Research).

[Source: H. Gao et al., A survey for foundation models in autonomous driving, https://arxiv.org/abs/2402.01105, 2024]

Use of FMs in online operations (with ASL, Stanford University)

- Building upon current black-box ML methodologies to safely deploy FMs to AVs



Uncertainty Quantification
- OOD Detection
- Conformal Prediction
- Mitigate impact of hallucinations

Runtime Monitoring & Guardrails
- Dynamic ODD fencing
- System-level safety assessment
- Safety fallbacks

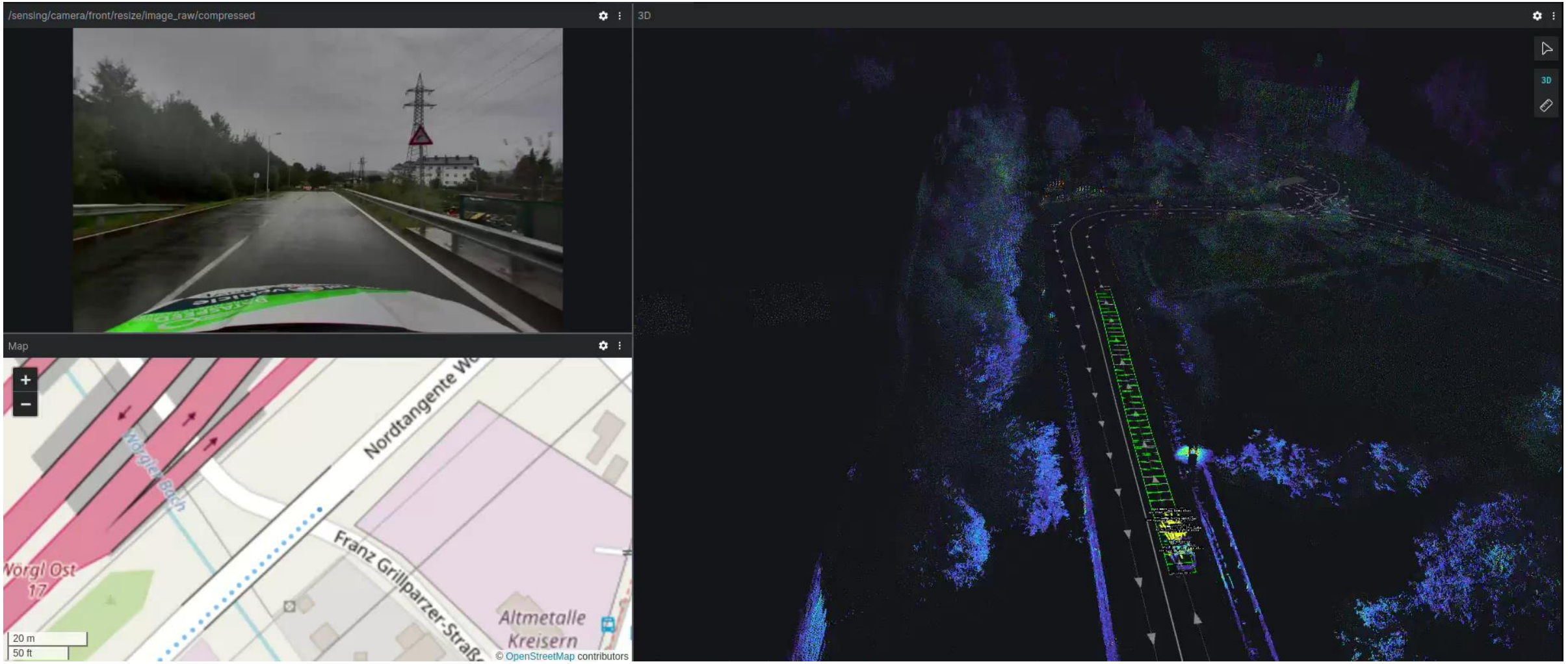
Rigorous Testing & Formal KPIs
- Formally derived safety metrics
- Held-out safety data
- Testing at scale with simulation

Sharma, Veer, Hancock, Yang, Pavone, Majumdar, *PAC-Bayes Generalization Certificates for Learned Inductive Conformal Prediction*, NeurIPS 2023

Veer, Sharma, Pavone. *Multi-Predictor Fusion: Combining Learning-based and Rule-based Trajectory Predictors*, CoRL 2023

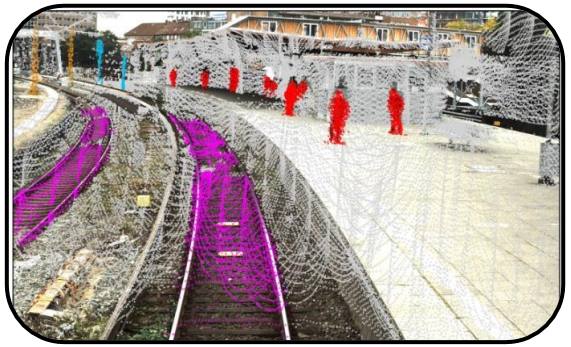
Elhafsi, Sinha, Agia, Schmerling, Nesnas, Pavone. *Semantic Anomaly Detection with Large Language Models*, Autonomous Robots 2023

AI-enabled autonomous driving at Virtual Vehicle Research

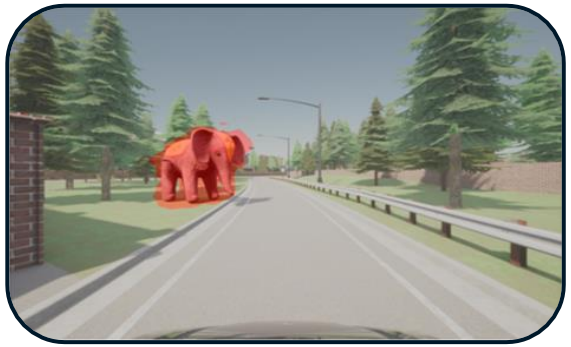


Safe AI in automated train operations

- Project “SafetrAIn” led by Siemens Mobility (duration: 2023-2025)
- Virtual Vehicle Research: Implementation of **AI-based perception**




Object detection

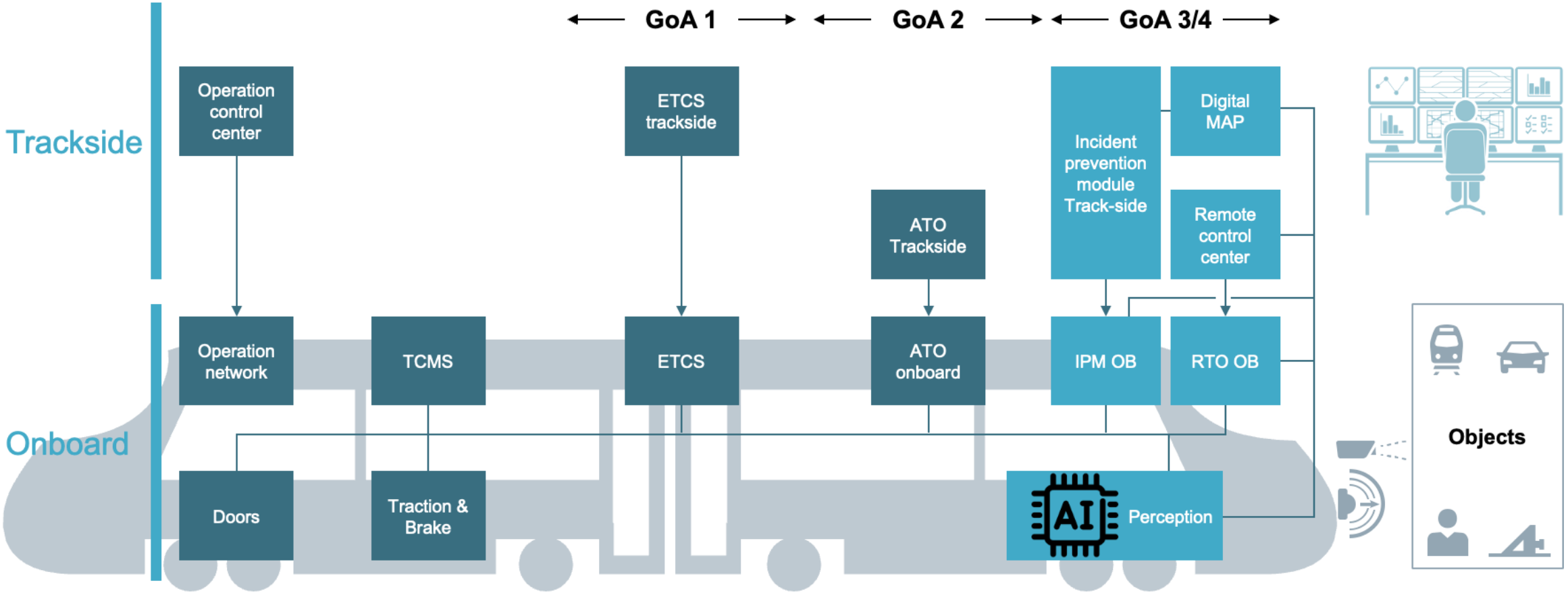



Out-of-distribution detection

- **AI-based perception:** Railway focuses on systems that replicate train operator capabilities, meet rail-specific needs (e.g., >600 m range), and operate reliably in all conditions.
- Anomaly detection

Safe AI in automated train operations

Safe AI in automated train operations



Key takeaways

Generative AI vs agentic AI

Generative AI

- Content creation & pattern-based responses
- Responds to specific prompts or inputs
- Decisions are made based on input
- **Output-oriented**
- Limited to content generation within training parameters
- **Static model**, requires retraining for adaption

Agentic AI

- Autonomous decision-making
- Continuously learns from interactions and outcomes
- Adaptive decision-making based on real-time data
- **Goal-oriented**
- Real-time environment
- **Utilizes tools and APIs**
- Basis for **agentic automation**

AI in mobility

AI in development

- Designing and optimizing ADAS and autonomous systems and SDVs
- Simulating driving environments
- Data analytics and predictive maintenance
- Code generation and code adaption

Safe AI (at the edge)

- Assessing safety of FMs using shell concept (uncertainty quantification / credible simulation – runtime monitoring and dynamic ODD fencing – rigorous testing / formal KPIs)

AI for data-driven decision-making

- **Decision-making and decision-making support** (under uncertainty): multi-modal data generation – GenAI for creating variants – computing uncertainties – reasoning – providing decisions

AI in Mobility

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